ECONOMIC COMPARISON OF FIVE SYSTEMS FOR DEVELOPING WATER RESOURCES FOR IRRIGATION IN BERRIEN COUNTY, MICHIGAN

Thesis for the Degree of M. S.

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ABSTRACT

ECONOMIC COMPARISON OF FIVE SYSTEMS FOR DEVELOPING WATER RESOURCES FOR IRRIGATION IN BERRIEN COUNTY, MICHIGAN

by Marvin N. Shearer

The purpose of this study was to analyze existing irrigation water development designs, costs, and procedures; and to analyze alternate development systems which might reduce development costs and the "surge" demands made on small streams.

Sixteen irrigation systems obtaining water from surface sources and twelve irrigation systems obtaining water from well sources were studied by farm survey. Wide variations were found in the design and operation of the systems which resulted in extreme differences in the cost of pumping water.

Five different systems for developing water for irrigation were studied by budgetary analysis. It was found that pumping direct from a surface source to a field lost some of its economic advantage over other systems when the water source and field were separated by a distance of 1000 feet or more at 16.6 and 33.2 gallons per minute per acre pumping capacities. Nearly all of the economic advantage was lost when the distance amounted to 2000 feet or more.

Use of small pump - holding pond combinations compared favorably economically with other methods and proved effective in reducing "surge" demands on small streams. In the example system used in this analysis the demand on the stream was reduced from 797 gallons per minute to 70 gallons per

minute while maintaining the same irrigation pump capacity.

Tables were developed which enable quick comparison of estimated pumping costs for 5 water development systems under a variety of water location and pump capacity situations. These comparisons can be useful as an aid in determining the most desirable type of water development system for a specific area to be irrigated.

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By

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CHAPTER I

INTRODUCTION

The development of the aluminum extruded pipe for portable sprinkler irrigation and the economically favorable agricultural situation following the Second World War made possible an expansion of sprinkler irrigation throughout the United States which often reached epidemic proportions. Irrigation appeared profitable and it followed that millions of dollars were invested in irrigation equipment.

Irrigation was practiced in the humid portion of the United States prior to 1900. Until recently, however, water users in this area had not been concerned about the consumptive nature of irrigation because the acreage irrigated and water consumed was small compared to the overall supplies. It was not until surface water shortages occurred that interest in water rights and the conservation of existing water supplies developed.

Within the last decade the nation has awakened to the seriousness of the dwindling water supply. There are now few organizations, or state or federal agencies concerned with natural resources that do not have an active program in some phase of water resource development. Cities have had to find new sources of water to supply the increased demand. Industrial and urban expansion in some areas has been limited because of inadequate water supplies. Stream pollution has become a problem. The farmer has had to take a second look at his rights associated with his immediate water supply and the supply he will need in the future.

Reason for This Study

Michigan has an abundance of ground water in many areas. Inventory reports prepared by the Michigan State Water Resources Commission show that much of this water is located at depths which should be economical for irrigation purposes. Because of the increasing competition for water by all users and the growing shortages in surface supplies during the low stream-flow periods, the development of ground water has become important to the general welfare of Michigan.[1]

Interviews with persons associated with water development suggest that one of the reasons that ground water has not been developed more extensively for irrigation is the assumption that ground water development costs are too high compared with development costs associated with surface sources.

Cursory study of the costs related to development of the two water sources, however, shows that as the distance between the land irrigated and the surface water source increases, development of ground water becomes more feasible until, it finally becomes more economical to develop than surface water.

Michigan operates under the riparian doctrine and as

[1]A. Allan Schmid discusses Michigan water problems in detail in Michigan Water Use and Development Problems, Michigan Agricultural Experiment Station Circular Bulletin 230, East Lansing, Michigan, 1961.

such, the legal aspects of water use for irrigation favor ground water as a source of supply. The use of surface water for irrigation is subject to challenge at any time. This becomes important economically when investments, usually amounting to thousands of dollars, are considered.

The relative costs of various systems of water development for irrigation are important in determining what water will be developed and how it will be developed for future irrigation use. Some systems can have important consequences on the general water supply picture because of their effect on the "surge" demands placed on small streams.

Previous Studies and Investigations

The Michigan Water Resources Commission found that irrigation of agricultural lands in Michigan increased from 2,550 acres in 1930 to 52,893 acres in 1959. Another 15,588 acres of cemeteries, parks, golf courses, and other miscellaneous areas were irrigated in 1959.[2] Figure 1 shows only slight tendency for the growth rate to decrease. Annual weather variation was a major influence on the increase in irrigated acreage during any one year.

The water applied to these lands was drawn from streams, excavated sumps, drain ditches, wells, and farm ponds. Figure 2 shows the sources of water for all irrigation in Michigan and in Berrien County in 1959.

The location of the irrigated areas in Michigan was most

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[2] Water Use for Irrigation (Lansing: Michigan Water Resources Commission, 1959), pp. 37-38.

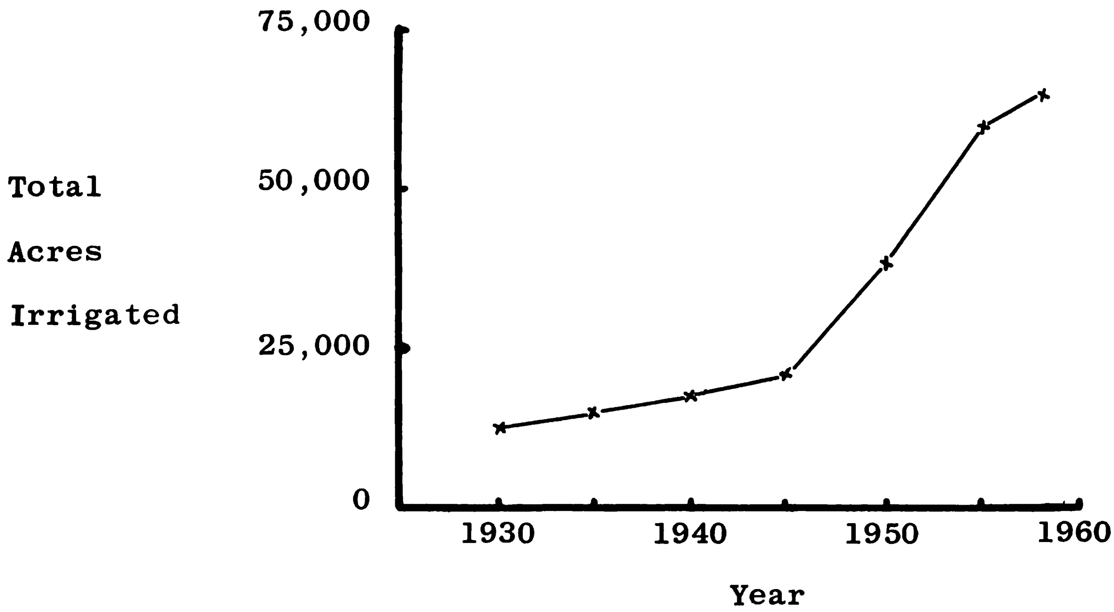

Fig. 1.--Total acres irrigated in Michigan by years.[3]

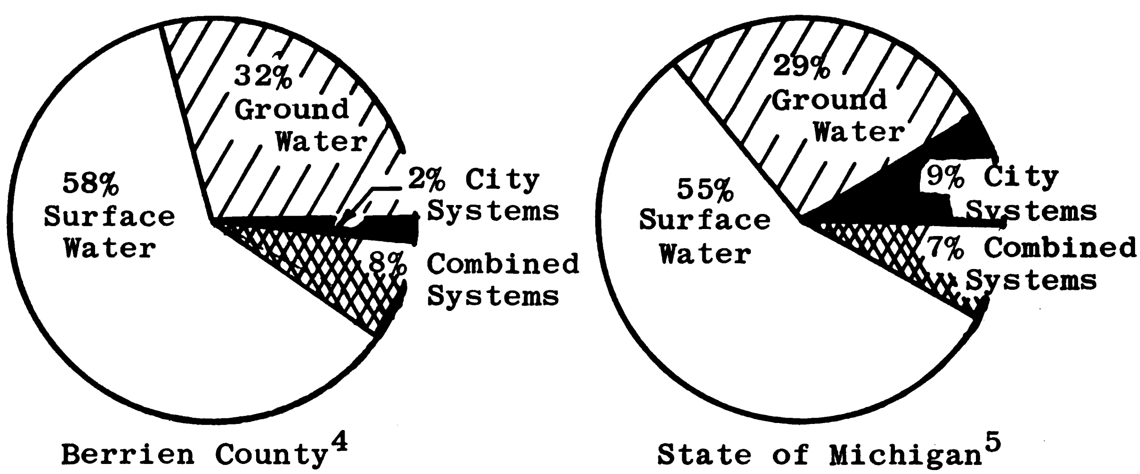

Fig. 2.--Sources of water for all irrigation purposes, 1959.

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[3]Ibid., pp. 39-40.

[4]Summary of Irrigation - Berrien County, Unpublished mimeograph prepared from information collected by Michigan Water Resources Commission by field interviews with irrigators. Field study was completed in April 1959.

[5]Water Use for Irrigation, p. 33.

concentrated in Berrien, Van Buren, and Wayne Counties which contained 34 percent of the total irrigated land.[6] These counties were major producers of high value vegetables and fruits.

Investments per farm in irrigation equipment was found by Hoglund, Kidder, and Vary to range from $700 to $50,000 on 176 farms studied in 46 counties of the lower peninsula in 1956. Ponds and reservoirs costing from $80 to $1000 were used by 40 percent of the farmers irrigating less than 30 acres. Ten 8-inch wells varying in depth from 95 feet to 290 feet cost from $1060 to $3850, and thirteen 10-inch wells varying in depth from 90 feet to 340 feet cost from $1100 to $4600. Annual charges for pump, power unit, and reservoir or well varied from 42 percent to 48 percent of the total cost of the irrigation systems. Annual fixed charges for the entire systems varied from $13 to $20 per acre irrigated.[7]

A number of studies have been made on the economics of irrigating certain crops in Michigan. These are summarized in Table 1. The difference in cost of irrigating field corn from wells and from surface sources was very slight - less than 8 percent.

In two different studies depreciation, interest, and repair of irrigation systems was found to vary from 41 percent

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[7]C. R. Hoglund, E. H. Kidder, K. A. Vary, "The Economics of Irrigating in Michigan," Quarterly Bulletin, Michigan Agricultural Experiment Station, Vol. 39, No. 1 (November, 1956), pp. 208-209.

TABLE 1.--Cost of irrigating specific crops in Michigan

Crop	Cost Per Ac. Inch	Ac. In. Applied	No. of Irri.	Total Irri. Cost Per Acre
Potatoes[a]	$7.72	3.6	2.9	$27.77
Pickling Cucumbers[b]	8.76	2.8	2.2	24.53
Field Corn[c] (using surface water)	3.24	6.0	3.0	19.43
Field Corn[d] (using wells)	3.50	6.0	3.0	21.00

[a]C. R. Hoglund, K. T. Wright, "Economic Analysis of the Michigan Potato Enterprise," Quarterly Bulletin, Michigan Agricultural Experiment Station, Vol. 42, No. 4 (May, 1960), pp. 686-703.

[b]C. R. Hoglund, "Economics of Growing and Irrigating Pickling Cucumbers," Quarterly Bulletin, Michigan Agricultural Experiment Station, Vol. 40, No. 4 (May, 1958), pp. 796-805.

[c]C. R. Hoglund, "Economics of Irrigating Corn, Quarterly Bulletin, Michigan Agricultural Experiment Station, Vol. 40, No. 3 (February, 1958), pp. 669-678.

[d]Ibid.

to 59 percent of the total annual cost of irrigation.[8,9]

Irrigation requirements in Michigan vary greatly from year to year. Kidder and Wheaton suggest a design capacity capable of applying up to 1½ inches per week under average conditions or up to 2 inches per week for crops which may be extremely sensitive to soil moisture conditions. They make no recommendation as to how many hours the irrigation system should be used per week to apply the recommended quantity of

[8]Hoglund, Quarterly Bulletin, Vol. 40, No. 3, p. 667.

[9]Hoglund, Quarterly Bulletin, Vol. 40, No. 4, p. 801.

water. However they do provide a formula by which a farmer can calculate the pumping capacity required to supply the required amount of water to a given acreage in a given number of pumping hours per week.[10]

Kidder and Davis suggest a minimum application rate of one-tenth to one-eighth of an inch per hour for frost protection.[11] This requires a pumping capacity of 45 and 57 gallons per minute per acre respectively.

Hoglund evaluated the occurrence of drought conditions based on weather bureau data at East Lansing. This is summarized in Table 2.

TABLE 2--Occurrence of various periods with less than 0.2 inches of rainfall per day for months of June, July, August, and September, 45 year period, 1911-1955, East Lansing, Michigan[12]

Consecutive Days With Less Than 0.2 Inches Per Day	No. of Years Occurring	Total No. of Times Occurring
1 week (5-9 days)	45	164
2 weeks (10-19 days)	42	134
3-4 weeks (20-29 days)	19	20
over 4 weeks (30 or more days)	6	8

[10]E. H. Kidder, R. Z. Wheaton, Supplemental Irrigation in Michigan, Extension Bulletin 309 (Revised), Michigan State University, October, 1958.

[11]E. H. Kidder, J. R. Davis, Frost Protection with Sprinkler Irrigation, Extension Bulletin 327 (Revised), Michigan State University, n.d.

[12]Hoglund, Quarterly Bulletin, Vol. 40, No. 3, p. 671.

Objective and Scope of This Study

The purpose of this study was two-fold, (1) to analyze existing irrigation water development designs, costs, and procedures; (2) to analyze alternate development systems which might reduce development costs and the "surge" demands made on small streams.

The study was conducted in one county. However, results are adaptable to the state-wide situation.

Berrien County was selected for this study because more than 14 percent of the irrigation in Michigan was carried on within its boundaries and because the proportion of irrigation from ground water and surface water sources in Berrien County was very similar to the state-wide irrigation withdrawals from these sources.

This was not an economic study of irrigation in the usual sense but rather a cost analysis study to justify and encourage development of water resources for irrigation in a manner that would reduce the "surge" demands placed on small streams, direct development of water used for consumptive purposes to a more secure source, and place the decision as to which water resource should be developed on an economic base.

CHAPTER II

ANALYSIS OF EXISTING IRRIGATION WATER DEVELOPMENT IN BERRIEN COUNTY

Definitions

A well is any artificial cased opening through which ground water is sought.

Ground water is water located beneath the soil surface which is sought through artificial cased openings.

Surface water is any stream, pond, reservoir or excavation other than a well from which water is obtained.

Total pumping cost includes annual charges for investments in: water source development, pump, motor, and mainline. It also includes the annual expenses for fuel and maintenance associated with delivering water to the edge of the field at 140 feet of pressure.

A surface system is an irrigation system which obtains water from a surface source.

A well system is an irrigation system which obtains water from a well.

The population is the group of irrigation farmers in Berrien County represented by the 1959 Water Use for Irrigation report of the Michigan Water Resources Commission.

The sample population is the group of farmers represented by the returned questionnaires sent out from the

Berrien County Agent's irrigation mailing list.

The sample is the group of farmers represented by the names drawn from the sample population.

Description of the Area

Berrien County is located in the southwestern corner of Michigan, bordering Lake Michigan on the west and Indiana on the south. The area is 569 square miles or 364,160 acres.[1] It contains less than 2 percent of the total cropland in Michigan, but over 14½ percent of the irrigated cropland.[2]

Major crops irrigated are small berries, fruits, and vegetables. Fifty-eight percent of the irrigated land receives water from surface sources; 32 percent receives water from ground supplies.[3]

The area is typified by "(1) A broken belt of high sand dunes, a quarter of a mile to a mile or more in width, bordering Lake Michigan along most of its front in the county; (2) a belt of undulating to level land, some 4 to 8 miles in width which includes some flat, poorly drained land and depressions or valleys between sand ridges; (3) a belt of higher gently rolling to hilly country, some 6 to 9 miles in width, occupying most of the central and eastern parts of the county;

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[1] J. A. Kerr, N. M. Kirk, Elbert Southworth, Soil Survey of Berrien County Michigan, U.S. Dept. of Agriculture (Washington: U. S. Government Printing Office, 1927), p. 1343.

[2] Water Use for Irrigation (Lansing: Michigan Water Resources Commission, 1959), p. 19.

[3] Summary of Irrigation - Berrien County, Unpublished mimeograph prepared from information collected by Michigan Water Resources Commission by field interviews with irrigators. Field study was completed in April, 1959.

(4) high, smooth to undulating and pitted outwash plains, occupying most of the southeastern part of the county; (5) the terraces of the St. Joseph and Paw Paw Rivers."[4]

The area is drained primarily by the Paw Paw River, the Galien River, and the St. Joseph River. The drainage areas are rolling, glaciated, ranging in elevation from 578 feet at Lake Michigan to about 800 feet elevation on the east.[5]

There appears to be no immediate problem of adequate water supplies from surface sources for lands adjacent to the main streams. Problems have occurred, however, in the small tributaries and in swampy areas where ponds are used.

Ground water is found in the glacial drift which varies in thickness from not less than 100 feet to more than 400 feet based on present records.[6] Wells are rarely over 200 feet deep.[7] In many instances ground water can be obtained in sufficient quantities at depths which can be reached by horizontal centrifugal pumps located on the surface of the ground. Acreage of land irrigated has in many cases been adjusted to the water supplies available.

Most of the irrigated agriculture has developed north of an east-west line drawn through Berrien Springs, and is located generally on the coarser textured soils.

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[4]Kerr, Kirk, Southworth, p. 1343.

[5]Ibid., p. 1345.

[6]Water Resource Conditions and Uses in the Paw Paw River Basin (Lansing: Michigan Water Resources Commission, 1955), p. 9.

[7]Personal inspection of field study records of the Michigan Water Resources Commission.

Procedure

Selecting Sample

Questionnaires were sent to approximately 400 persons on the Berrien County Agent's irrigation mailing list asking information about source of water, distance water is pumped to the first field and other information the County Agent desired for his files. Of one hundred seventy-nine returned, 13 indicated no irrigation and 24 were answered unsatisfactorily. The remaining questionnaires were separated into well system and surface system groups. Those which indicated both surface and well systems were put into the well system group unless it was apparent that the well system was supplemental to the surface system.

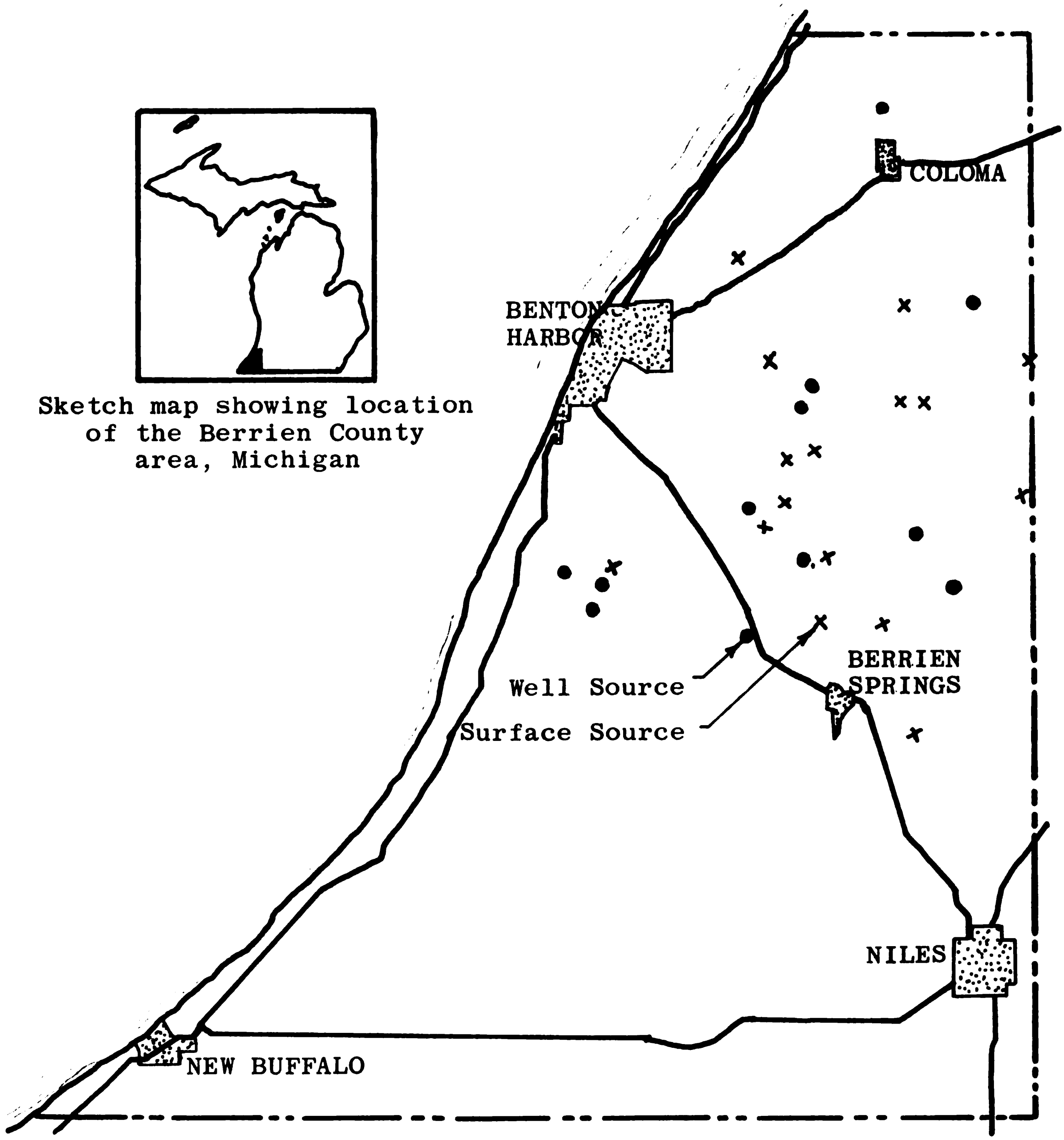
Those farmers irrigating less than 5 acres were removed from both groups. Thirteen cases were drawn at random from the well system group. One of these was later removed because the farmer was no longer irrigating.

Those farmers using surface water were divided into groups according to the distance between the water source and the field irrigated. Seven cases were drawn from the 0-999 foot group, 5 from the 1000-1999 foot group and 4 from the 2000 foot and over group.

The locations of the sample farms are shown in Figure 3.

Sample, Sample Population, Population Comparisons

Some information about the population of sprinkler systems in Berrien County was known. The sample was compared with



BERRIEN COUNTY

Fig. 3.--Location of Sample Farms

the sample population and/or the population in Tables 3, 4, and 5.

TABLE 3.--Percent of systems irrigating specified acreages

Acres Irrigated	Percent of Systems		
	Sample	Sample Population	Population[a]
0 - 9	7	21	30
10 - 19	18	31	31
20 - 29	21	16	16
30 - 49	47	18	13
Over 49	7	14	10

[a]*Water Use for Irrigation*, p. 22.

TABLE 4.--Percent of systems pumping water various distances

Distance from Water Source to Field	Percent of Systems	
	Sample	Sample Population
0 - 999 feet	44	50
1000 - 1999	31	32
2000 feet +	25	18

TABLE 5.--Percent of systems using wells and surface water sources

Source	Percent of Systems		
	Sample	Sample Population	Population[a]
Wells	45	27	32
Surface	55	73	68

[a]*Summary of Irrigation - Berrien County.*

Gathering Data

Data was obtained from the 29 farmers by personal interviews made by the author. A sample interview data sheet is shown on page 54.

The author was introduced to the farmers through a letter by Munns Caldwell, county agent with the Cooperative Extension Service in Berrien County. Appointments were made with each farmer by telephone the day prior to the visit by the interviewer. In all cases the interviewer was welcomed into the home and was frequently given access to the farm records for the purpose of obtaining the desired information. The respondents were very cooperative and did not hesitate in supplying any of the information requested.

Such items as investment, fuel consumption, maximum number of sprinklers used at one time, distance the water is pumped, and pipe sizes used should not be subject to either misinterpretation or excessive error. It is on these items that most of the calculations are based.

Computations

Fixed costs - all equipment was depreciated on a 15 year schedule. Wells were depreciated on a 30 year schedule and ponds were depreciated on a 10 year schedule. All interest on investments was calculated at 6 percent on one-half the investment. Repairs and maintenance of equipment was calculated at 3 percent of the initial investment per year.

Labor for putting up and taking down the system was charged at $1.00 per hour.

Fuel and oil costs were combined and computed at $0.23 per gallon of gasoline.

Electricity costs were estimated at $0.0225 per horse-power hour ($0.03/kwhr.).

Pumping rates given by farmers were checked against fuel consumption and the maximum number of sprinklers in operation at one time. When there were extreme differences, the pump pressure and sprinkler capacities were used as a guide.

Hours of operation varied considerably from year to year. The maximum hours systems were used in either 1959 or 1960 was recorded. The hours of operation were determined first by estimating, then by enumerating, then by checking when possible against annual fuel consumption.

Presenting Data

The total cost of delivering one acre-inch of water to the edge of the field being irrigated under a pressure of 140 feet was calculated.[8] No equipment or labor expenses beyond the edge of the field being irrigated were included. Characteristics of the systems and the total pumping cost per acre inch were compared to determine existing relationships.

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[8] This cost should not be confused with the cost of applying an acre-inch of water which is the basis for analysis used in most irrigation studies.

Analysis of Data

Description of Systems

Investment

It was expected that the investment in pumping equipment, reservoirs, and wells would tend to increase as the acreage irrigated increased. Figure 4 shows there was a wide scatter of investments with only a slight tendency for them to go up with an increase in acres irrigated. The variation in investments for the same acreage irrigated was caused by a number of factors including differences in equipment requirements, the availability of low cost pumping units which were incorporated into some of the systems, and lack of appropriate design.

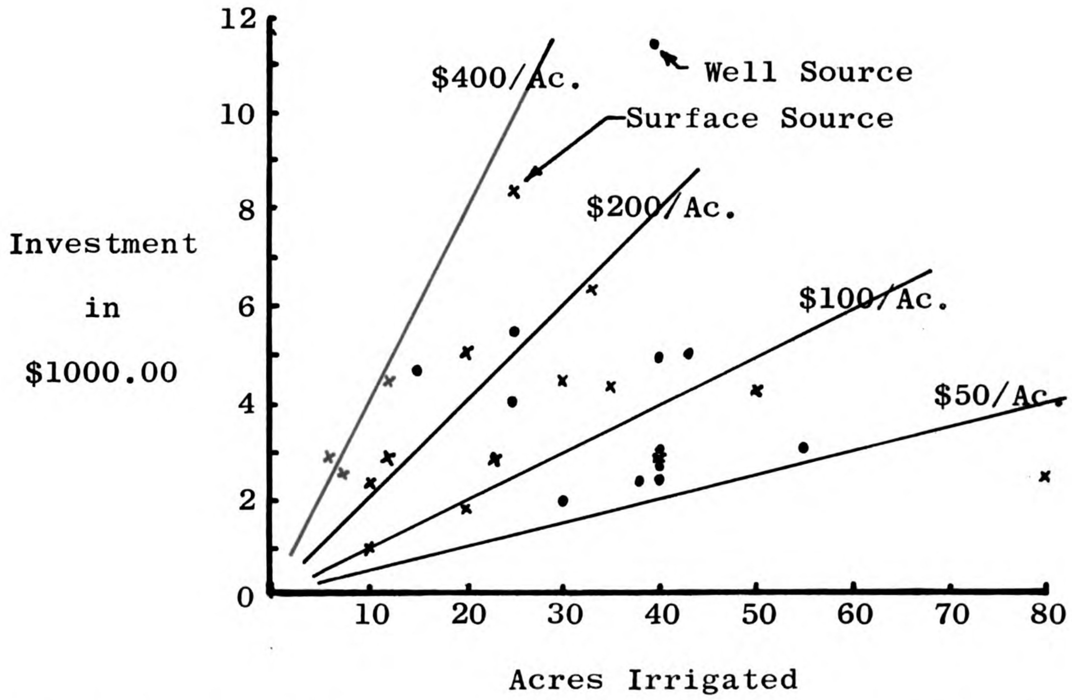

Fig. 4.--Relationship of acres irrigated and investment in pumping equipment, mainline, and reservoir or well.

Pumping Capacity

It was expected that the pumping capacity of the systems would tend to increase as the acres irrigated increased. Figure 5 shows that this did not occur. There were wide variations in the pumping capacity of the systems on a per acre basis. In general, pumping capacities were much higher for surface systems than for well systems. Only one well system, as contrasted to 9 surface systems, had a capacity over 20 gallons per minute per acre.

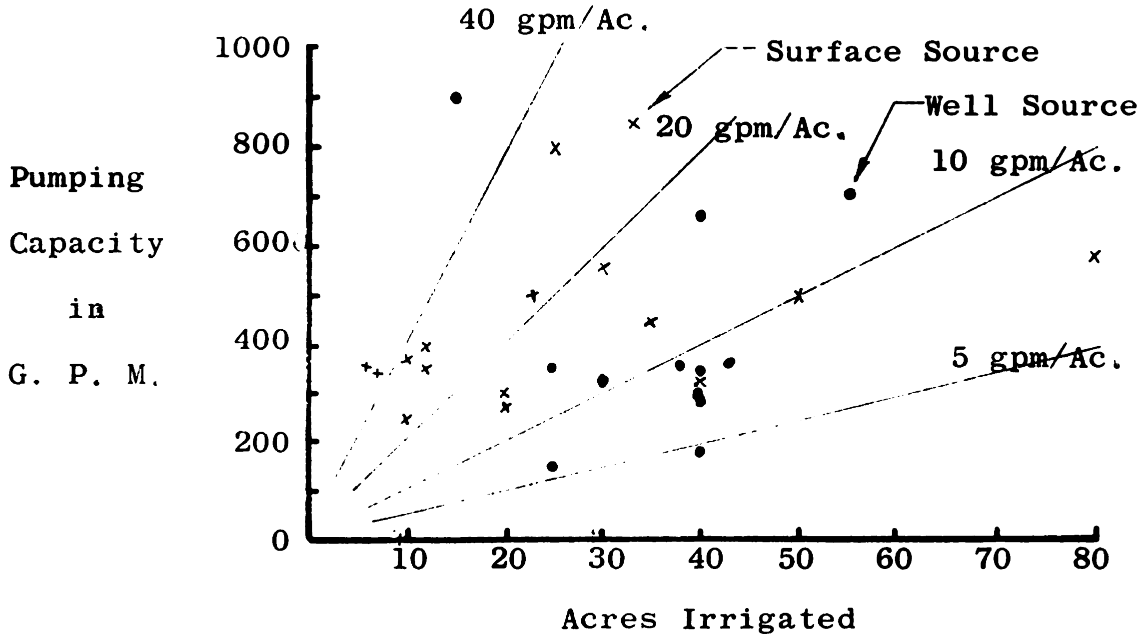

Fig. 5.--Relationship of acres irrigated to pumping capacity.

Hours Used Per Year

It was expected that the greater the pumping capacity per acre, the fewer hours the system would tend to be operated per year since it could apply the same quantity of water in less time. Figure 6 shows that this relationship did not exist.

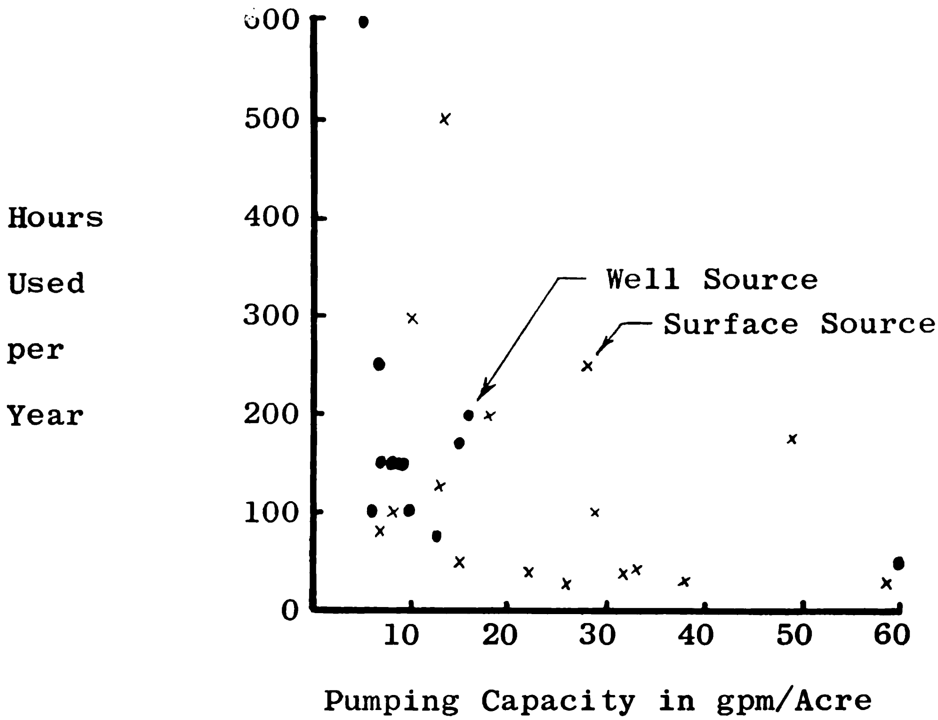

Fig. 6.--Relationship of pumping capacity to hours used per year.

Cost of Ponds

There was no relationship found between the cost or size of the ponds and acres irrigated, but there was a good relationship, as seen in Figure 7, found between cost of ponds and capacity of ponds. The mean cost per cubic foot of excavated material was $0.005 or $0.136 per cubic yard.

Pumping Cost

Cost of pumping water under pressure to the field being irrigated is affected by a number of factors. Whenever any one of these factors shows a relationship to the cost of pumping, the economic effect of this factor becomes impor-

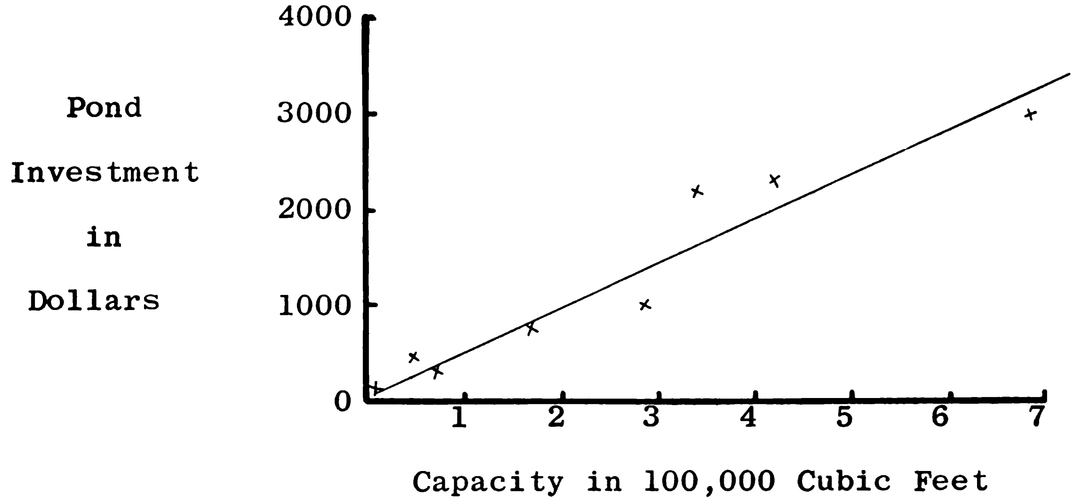

Fig. 7.--Relationship of pond capacity to pond investment.

tant and the management of the irrigation program and system should be analyzed with respect to it. Some of these factors are more important economically than others.

A number of these factors were compared with the cost of pumping an acre-inch of water under a pressure of 140 feet to the edge of the field being irrigated.

Pumping Cost Related to Distance That Water Was Pumped

It was expected that due to increased investment in pipe, increased power requirements needed to overcome pipe friction, and increased labor required to put up and take down additional mainline pipe, the cost of pumping water would tend to increase as the distance it was pumped increased. Figure 8 shows that this relationship did not exist. Other factors screened the effect of distance on pumping costs.

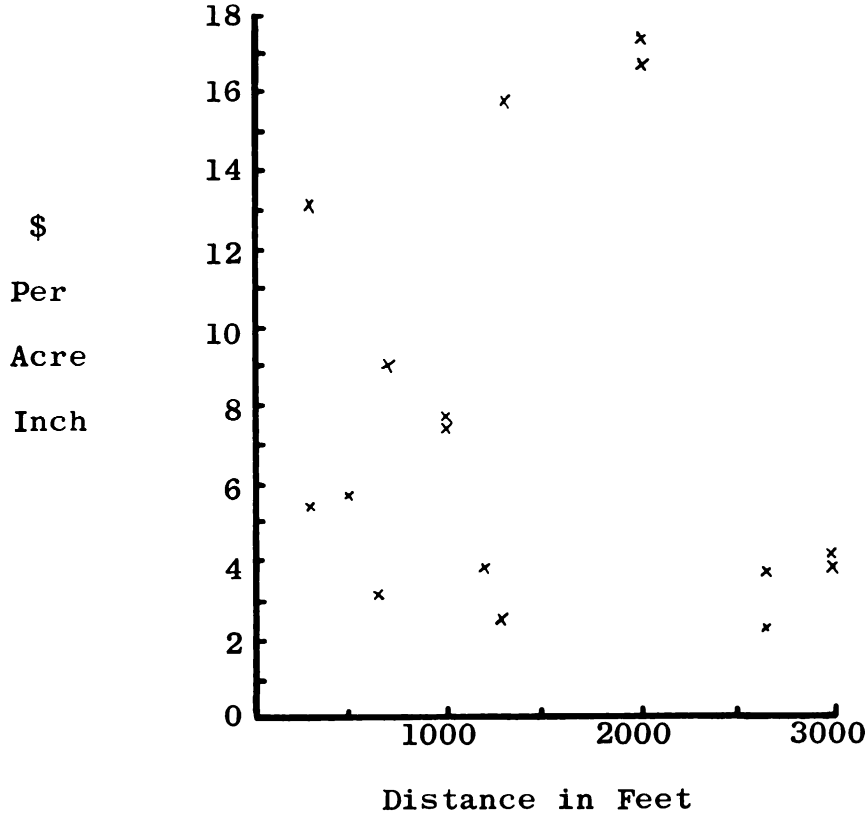

Fig. 8.--Relationship of distance between the surface water source and the field irrigated to total pumping cost per acre-inch.

Pumping Cost Related to Capacity Per Acre

It was expected that as the pumping capacity per acre increased, the cost per acre-inch of water pumped would tend to increase due to the larger equipment required to handle the increased quantity of water. Figure 9 shows that the slight tendency for this to be true was masked by the wide variation between systems. This variation was caused principally by the variation in prices paid by farmers for almost

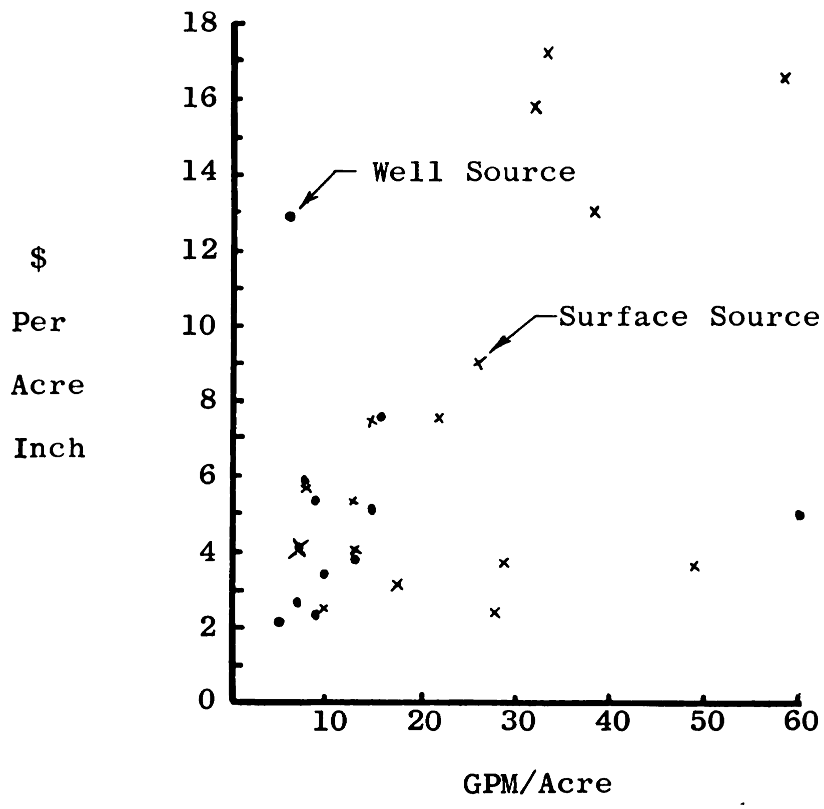

Fig. 9.--Relationship of pumping capacity to total pumping cost per acre-inch.

identical equipment, the cost and type of equipment required for different water source situations, and the quantity of water pumped annually to which fixed costs were assigned. The wide variation in the fixed costs per acre-inch of water pumped is shown in Figure 10.

Pumping Cost Related to Hours Used Per Year

It was expected that the more hours a system was used per year, the lower the cost per acre-inch of water pumped would tend to be. This relationship should exist due to the spreading of the fixed costs over a longer operating period.

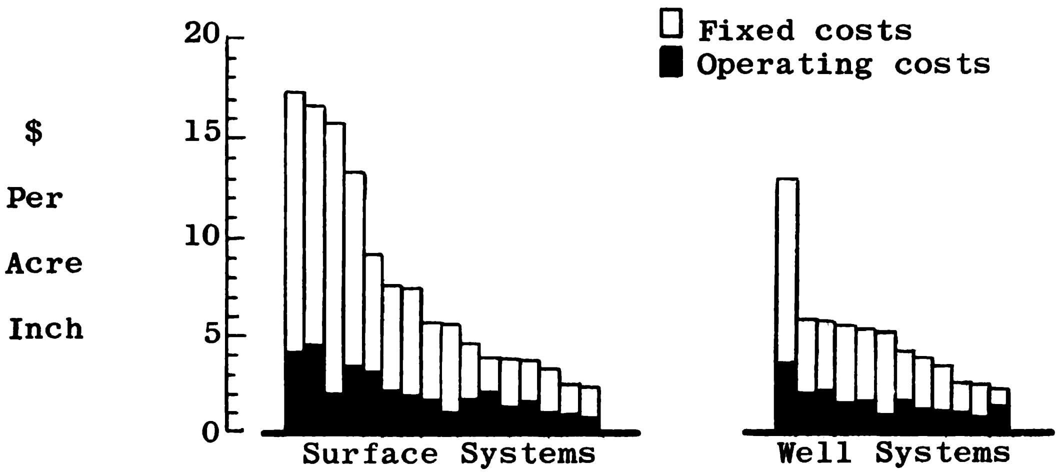

Fig. 10.--Relationship of source of water for individual systems to total pumping, fixed, and operating costs per acre-inch.

Figure 11 shows that this relationship did exist. It is interesting to note that there was more variation in the costs for well systems than for surface systems, This was caused by the wide variation in well construction and pump requirements needed to meet the variety of situations where well sources were developed.

Cost of Pumping Related to Source of Water

It had been generally accepted that the cost of pumping from wells was higher than pumping from surface sources. Table 6 shows that this assumption was not valid and this comparison could not be made due to the wide variation within each system type. Comparisons could be made only between specific system situations.

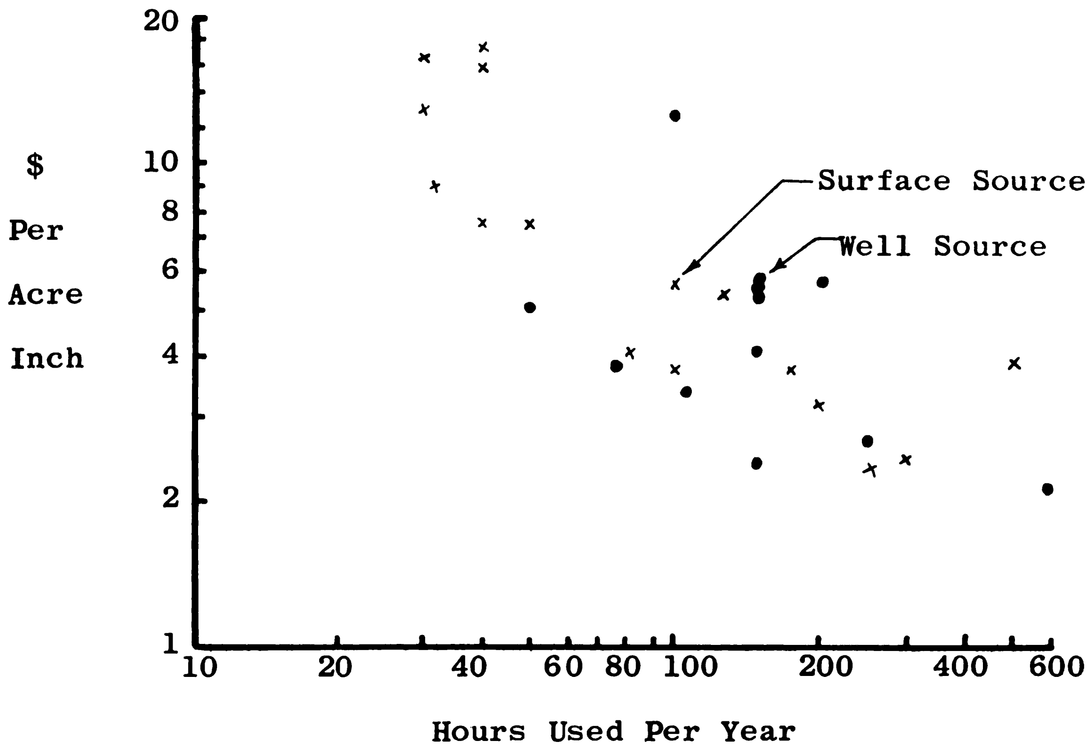

Fig. 11.--Relationship of hours used per year to total pumping cost per acre-inch.

TABLE 6.--Cost of pumping an acre-inch of water with surface and well systems

Surface System		Well System
$17.39 per Ac. In.		$12.91 per Ac. In.
16.39		5.80
16.84		5.76
13.22		5.39
9.06		5.17
7.66		5.05
7.56	Common Median	4.07
5.73		3.82
5.40		3.37
4.06		2.64
3.93		2.39
3.78		2.13
3.72		
3.19		
2.44		
2.34		

Cost of Pumping Related to Acres Irrigated

It was expected that the cost of pumping an acre-inch of water would tend to decrease as the acres irrigated increased due to more efficient utilization of a larger system. Figure 12 shows a tendency for this to be true but the variation in costs for systems irrigating less than 30 acres was so great that this relationship becomes obscure.

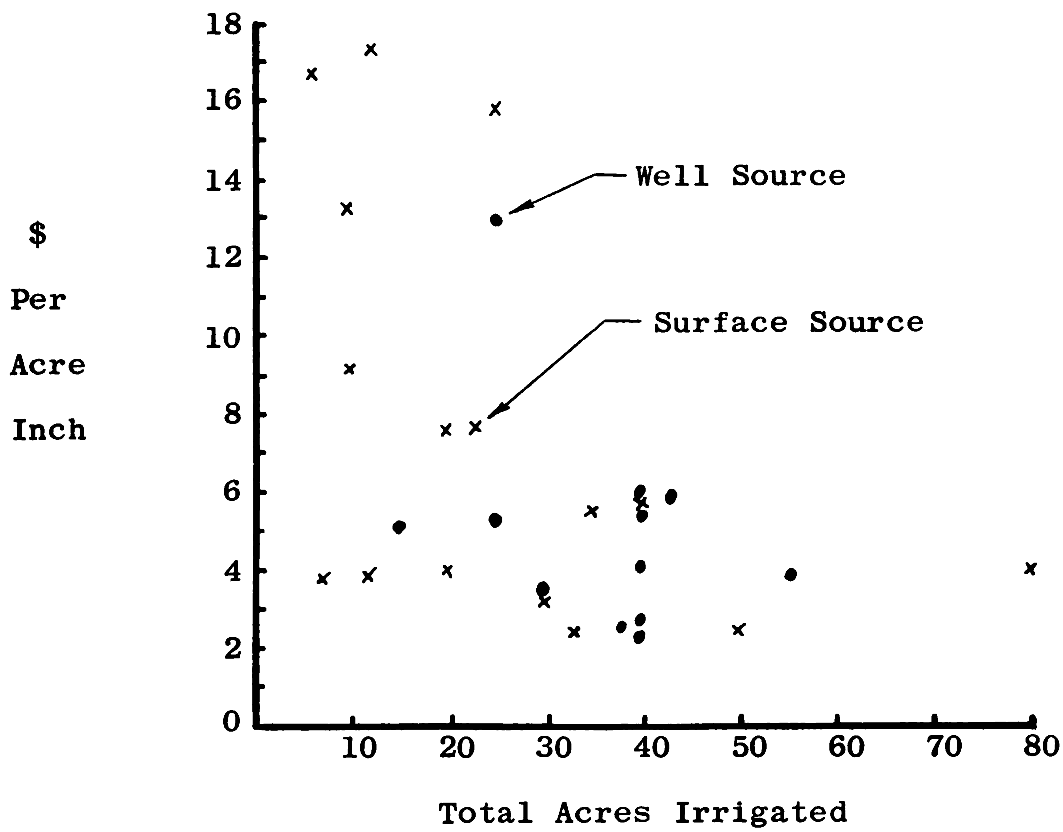

Fig. 12.--Relationship of total acres irrigated to total pumping cost per acre-inch.

Summary Chapter II

Description of Systems

The wide variation found in the cost of pumping a given quantity of water with the systems studied indicates a lack of thorough consideration of both design and operation alternatives.

Capacities of surface systems varied from 7 to 58 gallons per minute per acre with a median of 27, and well systems varied from 5 to 60 gallons per minute per acre with a median of 9.

Investments for surface systems varied from $30.00 to $490.00 per acre with a median of $170.00, and well systems varied from $60.00 to $307.00 per acre with a median of $75.00.

Hours surface systems were used per year varied from 30 to 500 hours with a median of 90, and well systems varied from 50 to 600 hours with a median of 150.

Pond investments varied from $150.00 to $5000.00 per pond with an average earth moving cost of $0.136 per cubic yard.

Cost of Pumping

Cost of pumping water varied from $2.34 to $17.39 per acre-inch with a median of $5.56 for surface systems, and from $2.13 to $12.91 per acre-inch with a median of $4.56 for well systems. The common median was $5.11 per acre-inch. Wide variations prevented any meaningful pumping cost comparison between surface and well systems as groups.

The number of hours the irrigation systems were used had more effect on the cost of pumping an acre-inch of water than any other single item. This suggests the economic importance of finding additional uses for existing systems and also the importance of purchasing sprinkler systems initially designed with lower per acre pumping capacities so they can operate over a greater period of time annually. Figure 8 shows the economic importance of fixed costs per acre-inch of water pumped. Those systems operated for the shortest period of time each year had the largest fixed costs per unit of water pumped.

CHAPTER III

BUDGETARY ANALYSIS OF ALTERNATE SYSTEMS FOR DEVELOPING WATER FOR IRRIGATION

It is important that farmers planning on developing water for irrigation study alternate development possibilities from both an economic and water supply standpoint. Five systems of developing water for irrigation were here evaluated: (1) Direct pumping from streams, (2) Direct pumping from wells, (3) Small centrifugal pump at stream used in conjunction with holding pond and irrigation pump at the field irrigated, (4) Small turbine at well used in conjunction with holding pond and irrigation pump at the field irrigated, and (5) Rented well and pump used in conjunction with holding pond and irrigation pump at the field irrigated.

General Criteria Assumed for Design of Systems

Irrigation Criteria

Size of irrigated area per farm	24 acres[1]
Gross annual application	6 inches[2]
Peak rate of consumptive use . .	0.22 inches per day[3]

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[1]Michigan Water Resources Commission 1959 report showed average sized area irrigated per system to be 26.37 acres in Michigan and 23.15 acres in Berrien County.

[2]Requirements for specific crops may vary from one to 10 inches. Six inches was considered an average assuming that more than one crop was irrigated with the system.

[3]Kidder and Wheaton, p. 9.

Equipment Capacities

GPM/Acre	Total GPM	% of Time in Operation (Peak)	Hrs. Used Per Year
11.8	283	50	230
16.6	393	36	164
33.2	797	18	81

Depreciation and Interest Schedule

Unit	Depreciation Period	Interest	Annual Maintenance
Pump, motor mainline, etc.	15 years	0.06	0.03 x Invest.
Pond	10	.06	none
Well	30	.06	none

Procedure

Costs of equipment and services required to develop water for irrigation were obtained from dealers serving Berrien County. The total cost of pumping one acre-inch of water under a head of 140 feet to the edge of the field irrigated was computed for the five systems. The assumed criteria and data pertaining to the design of the systems is found on pages 28, 29, and 48 through 52.

In the summary analysis, the cost of pumping an acre-inch of water with each of the five systems of water development was compared to determine the relative economic merits of each.

Analysis of Systems

System A

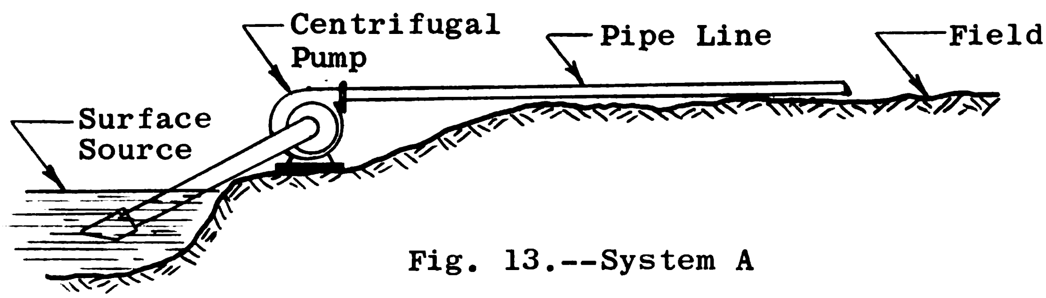

Fig. 13.--System A

Water was pumped directly from a surface source to the field being irrigated as shown in Figure 13. The distance from the water source to the field varied from 0 to 4000 feet. Results are shown graphically in Figure 14 and in tabular form in Table C of the appendix.

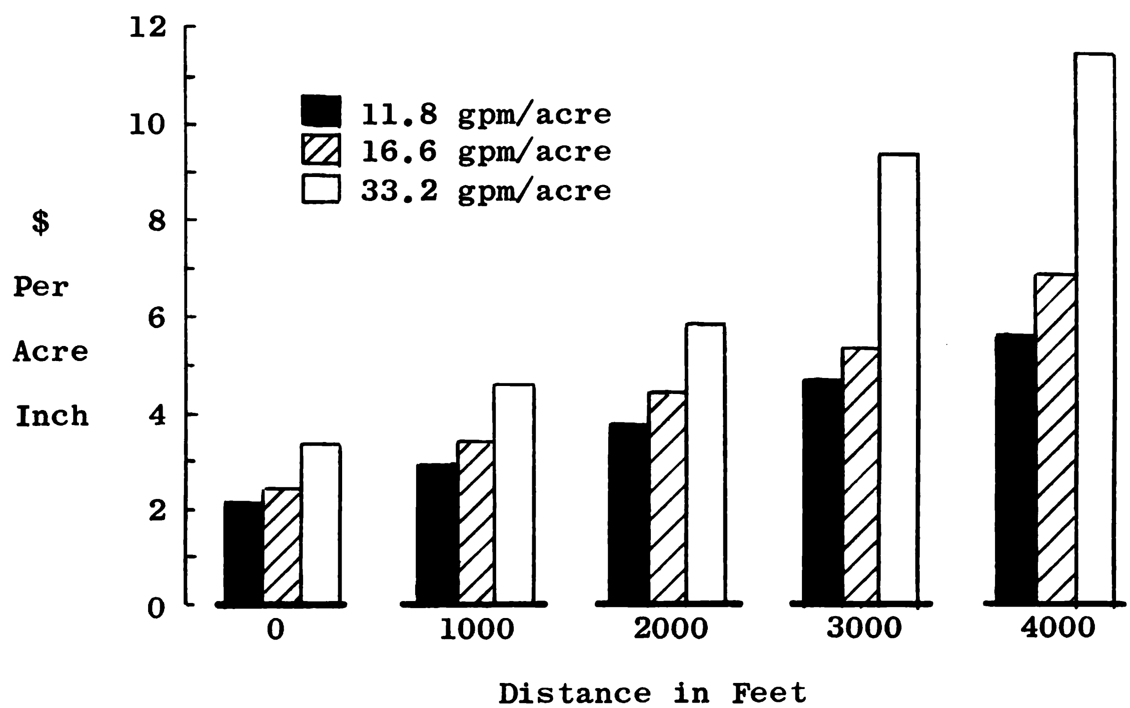

Fig. 14.--Relationship of distance between surface source and field irrigated to total pumping cost per acre-inch for System A.

Increasing the capacity from 11.8 gallons per minute per acre to 33.2 gallons per minute per acre increased the total pumping cost $0.84 per acre-inch when the field was adjacent to the water source and $5.86 per acre-inch when the field was 4000 feet from the water source.

As the distance from the water source to the field increased from 0 to 4000 feet, the total pumping cost increased $2.54 per acre-inch for a capacity of 11.8 gallons per minute per acre and $8.17 per acre-inch for a pumping capacity of 33.2 gallons per minute per acre.

System B

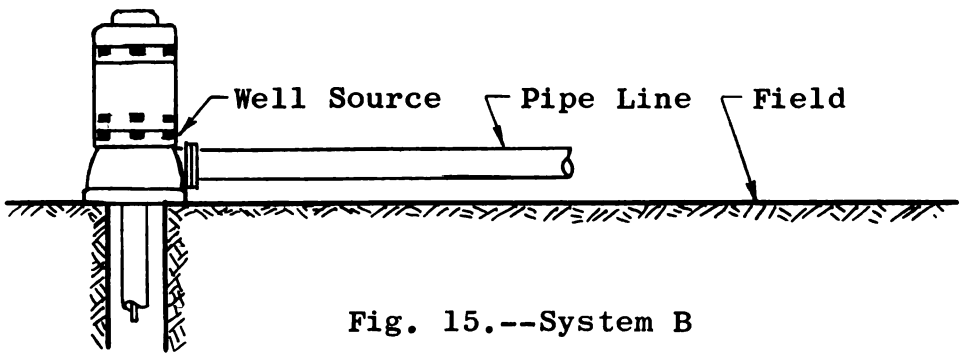

Fig. 15.--System B

Water was pumped directly from a well located in or adjacent to the field being irrigated as shown in Figure 15. Calculations were made for 3 pump settings, 3 well depths and 3 system capacities. Results are shown graphically in Figure 16, and in tabular form in Table e of the appendix.

Increasing the capacity from 11.8 gallons per minute per acre to 33.2 gallons per minute per acre increased the

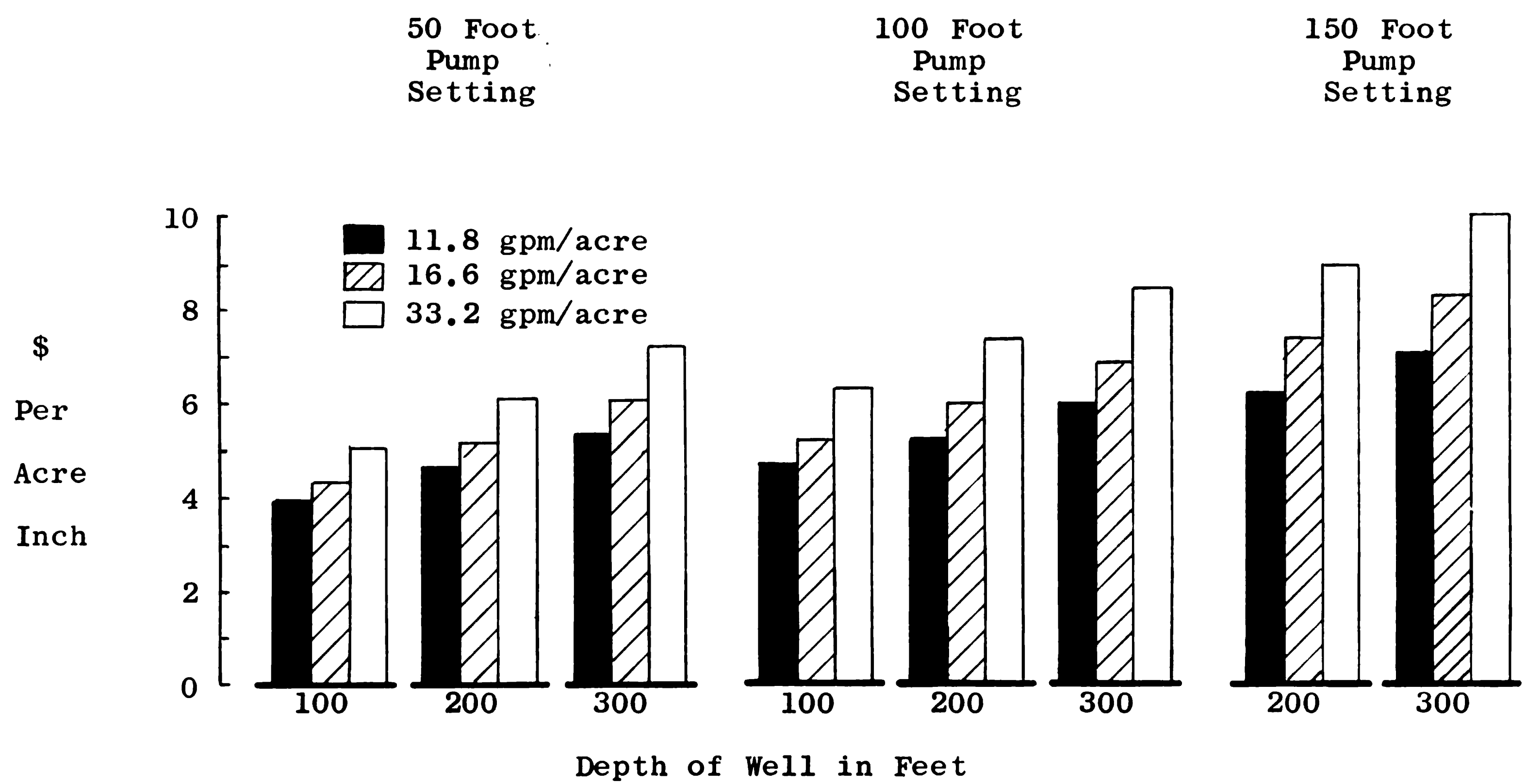

Fig. 16.--Relationship of depth of well and pump setting to total pumping cost per acre-inch for System B.

total pumping cost $1.15 per acre-inch at the 50 foot pump setting with a 100 foot well depth and $3.05 per acre-inch at the 150 foot pump setting with a 300 foot well depth.

Increasing the well depth from 100 feet to 300 feet increased the total pumping cost $1.41 per acre-inch with the 50 foot pump setting and 11.8 gallons per minute per acre capacity, and $1.42 per acre-inch with the 100 foot pump setting and 11.8 gallons per minute per acre capacity.

Increasing the pump setting from 50 feet to 150 feet in a 200 foot well increased the total pumping cost $1.56 per acre-inch at a pumping capacity of 11.8 gallons per minute per acre and $1.77 per acre-inch at a pumping capacity of 33.2 gallons per minute per acre.

System C

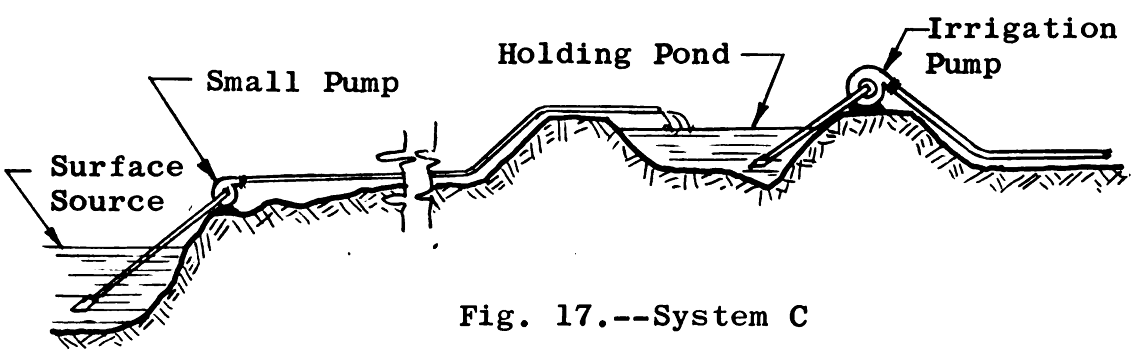

Fig. 17.--System C

Water was pumped from a surface source with a small electric pump at a rate of 70 gallons per minute as shown in Figure 17. The 4 acre-foot holding pond[4] and small pump had a combined capacity sufficient to furnish 24 acres with three

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[4]See page 54 for operation of pump-holding pond combination.

1½-inch irrigations in 3 weeks. The irrigation pump was identical to the one used in System A when the land irrigated was located adjacent to the water source.

The distance from the water source to the field irrigated varied from 1000 to 4000 feet. Results are shown graphically in Figure 18 and in tabular form in Table f of the appendix.

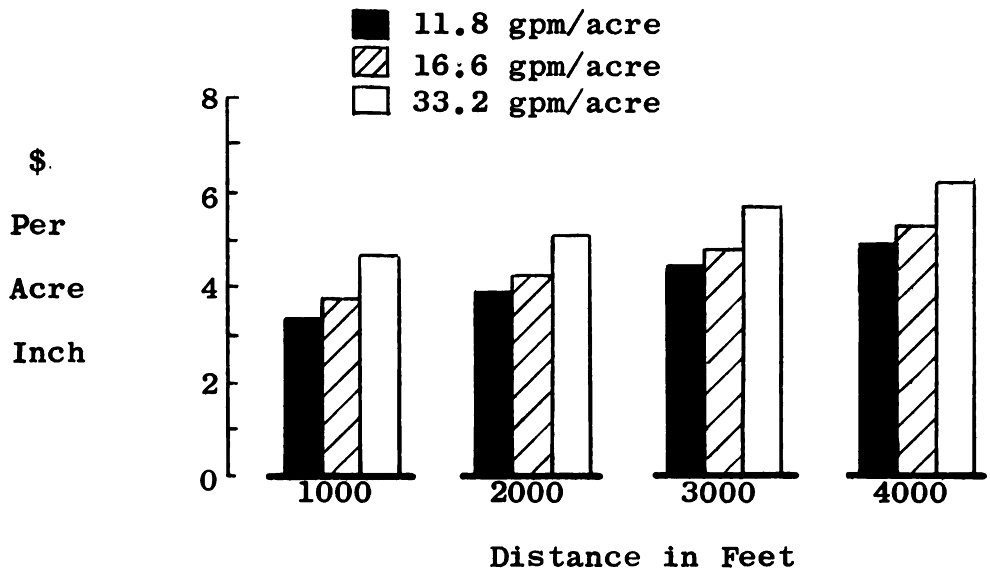

Fig. 18.--Relationship of distance between surface source and holding pond to total pumping cost per acre-inch for System C.

Increasing the irrigation pumping capacity from 11.8 gallons per minute per acre to 33.2 gallons per minute per acre increased the total pumping cost $1.23 per acre-inch when the field and pond were located at any specific distance from the water source.

Increasing the distance from the source of water to the pond from 1000 feet to 4000 feet increased the total pumping cost $1.58 for all three irrigation pump capacities.

System D

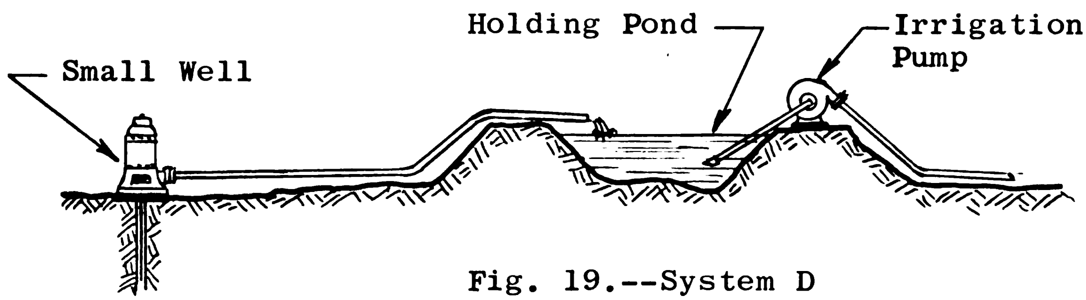

Fig. 19.--System D

Water was pumped from a small well with a 70 gallons per minute capacity electric turbine to a holding pond as shown in Figure 19. The 4 acre-foot pond and turbine had a combined capacity sufficient to furnish 24 acres with three 1½-inch irrigations in 3 weeks. The small well and holding pond were located adjacent to the field irrigated. The irrigation pump was identical to the one used in System A when the land irrigated was located adjacent to the water source. Three well depths, three pump settings, and three irrigation capacities were considered. Results are shown graphically in Figure 20, and in tabular form in Table g of the appendix.

Increasing the irrigation pump capacity from 11.8 to 16.6 gallons per minute per acre increased the total pumping cost $0.35 per acre-inch, and from 16.6 gallons per minute per acre to 33.2 gallons per minute per acres increased the total pumping cost $1.23 per acre-inch in all cases.

Increasing the well depth from 50 feet to 100 feet increased the total pumping cost $0.46 per acre inch with a 25 foot pump setting.

Increasing the pump setting from 25 to 125 feet in the 150 foot well increased the total pumping cost $1.07 per acre-inch.

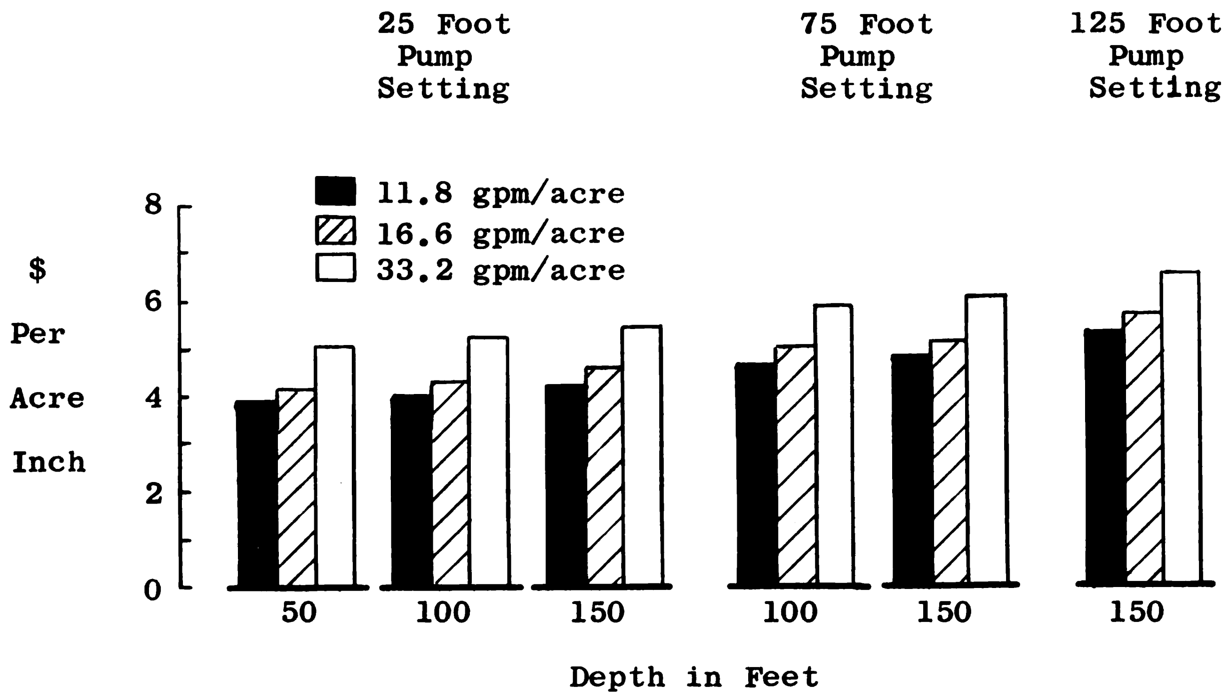

Fig. 20.--Relationship of depth of well and pump setting to total pumping cost per acre-inch for System D.

System E

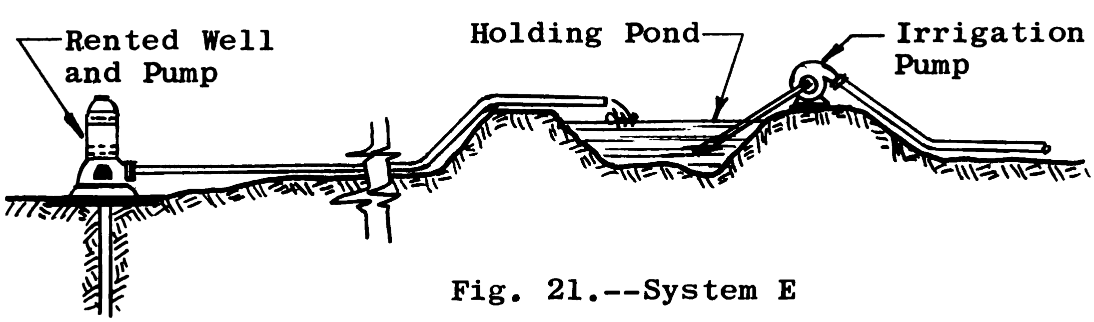

Fig. 21.--System E

Water was purchased from a neighbor at a charge of one-half the fixed cost per acre-inch of water plus the fuel cost per acre-inch based on the neighbor's cost. This amounted to $2.44 per acre-inch for a 50 foot pump setting in a 100 foot well and a pumping capacity of 283 gallons per minute.

Water was stored in a 4 acre-foot holding pond located adjacent to the field irrigated as shown in Figure 21. Three-inch aluminum mainline was used to convey the water from the pump to the pond. The distance from the well to the pond varied from 1000 feet to 4000 feet.

The irrigation pump identical to the one used in System A when the land irrigated was adjacent to the water source was used to pump the water from the pond to the field.

Results are shown graphically in Figure 22 and in tabular form in Table h of the appendix.

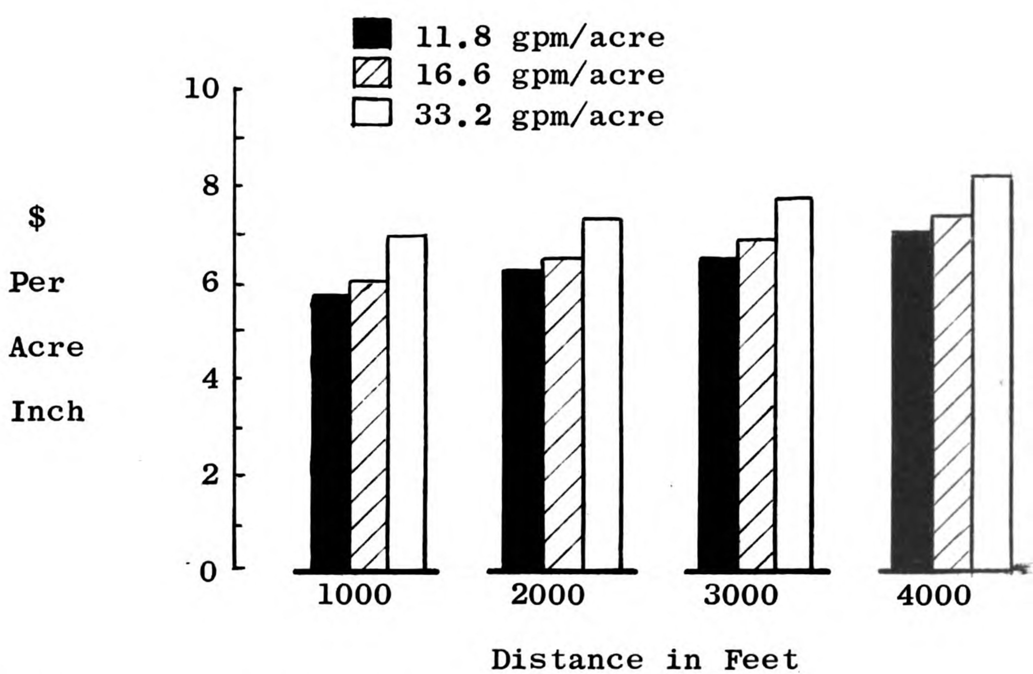

Fig. 22.--Relationship of distance between rented well and holding pond to total pumping cost per acre-inch for System E.

Increasing the irrigation pump capacity from 11.8 gallons per minute per acre to 33.2 gallons per minute per acre increased the total pumping cost $1.23 per acre-inch for all situations.

Increasing the distance between the pond and the well from 1000 to 4000 feet increased the total pumping cost $1.39 per acre-inch.

Summary of Chapter III

The graphic summary of pumping costs for the five different systems (Figure 23) includes all of the situations of Systems A, C, and D for which computations were made, but only the 50 foot pump setting situations for System B and the 25 foot pump setting situations for System D.

When the field irrigated was located 1000 feet or less from a surface source of water, it was more economical to use System A with a pumping capacity of 11.8 gallons per minute per acre than any other. It made little difference however, whether System A, B, C, or D was used at a pumping capacity of 33.2 gallons per minute per acre at 1000 feet distance.

The effect of the distances involved in Systems A, C, and E were directly comparable. With the field irrigated located 2000 feet from the surface source of water, System A had an advantage at 11.8 gallons per minute per acre capacity. System C had a decided advantage however, with the field located 2000 feet from the surface source, at the 16.6

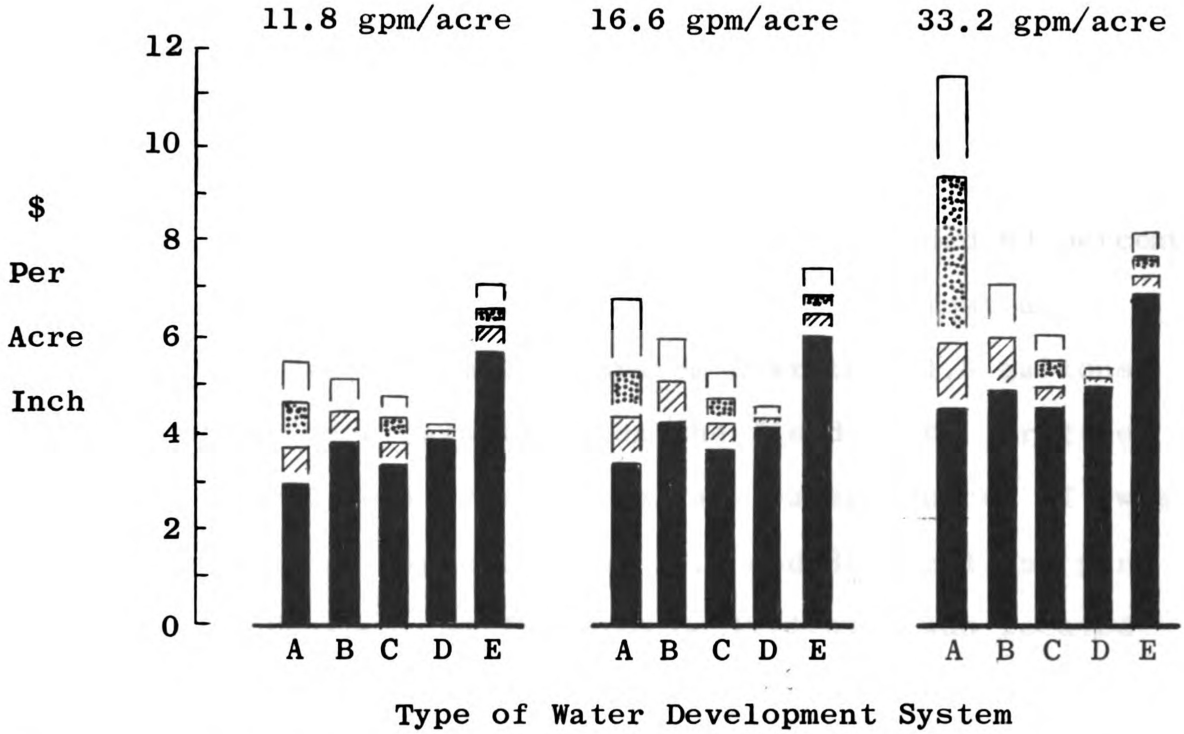

Fig. 23.--Relationship of five water development systems operating under various situations and at three pumping capacities to total pumping cost per acre-inch.

System	Key	Ft.	Situation Description
"A" - Pumping direct from surface source to field.		4000 3000 2000 1000	Distance from surface water source to field.
"B" - Pumping direct from well (located at field) to field.		300 200 100	Well depth with 50 foot pump setting.
"C" - Small centrifugal pump at stream source holding pond and irrigation pump at field.		4000 3000 2000 1000	Distance from surface source to pond.
"D" - Small turbine at well with holding pond & irrigation pump at field.		150 100 50	Well depth with 25 foot pump setting.
"E" - Rented well with holding pond and irrigation pump at field.		4000 3000 2000 1000	Distance from rented well to pond.

gallons per minute per acre and 33.2 gallons per minute per acre capacities and at all capacities when the field was located 3000 feet or more from the surface source.

When ground water was available in a 100 foot well and a 50 foot pump setting was adequate (this included 83 percent of the wells included in the sample), it was almost as economical to use System B as System A at the 11.8 gallons per minute per acre capacity when the field to be irrigated was located 2000 feet from the surface water source. It was more economical at capacities of 16.6 and 33.2 gallons per minute per acre when the field to be irrigated was located 2000 feet from the surface water source and at all capacities when the field was located 3000 and 4000 feet from the water source.

CHAPTER IV

CONCLUSIONS AND IMPLICATIONS

Conclusions

In general, irrigation systems studied in Berrien County exhibited a lack of consideration of alternatives. This resulted in excessive variation of irrigation costs.

There was no justification for assuming that either surface systems or well systems were more expensive than the other. The wide variation in total pumping cost found among systems using like water sources indicates that any such comparison would be valid only if it were made between specific systems in either category.

The use of small pumps at surface and well sources used in conjunction with holding ponds and irrigation pumps compared favorably with all other methods studied for developing water for irrigation when the distance between the surface source to the field irrigated was 2000 feet or more, and under certain conditions when the distance was 1000 feet or more.

At the rental charge assumed in this study, use of a rented well in conjunction with a holding pond and irrigation pump did not compare favorably with any other system under any situation except direct pumping from a surface source to the field being irrigated at a rate of 33.2 gallons per minute per acre when the source and field were separated by a distance of 4000 feet or more.

"Surge" demands placed on small streams could be reduced appreciably by use of a small pump and holding pond combination in place of direct pumping from a surface source to the field irrigated. In this study the pumping demand placed on the stream was reduced from 797 gallons per minute to 70 gallons per minute while maintaining same irrigation pump capacity.

Implications

Although this study was made in only one county, it is the author's opinion after visiting with academic, professional and lay people, and studying publications concerned with water resource development in Michigan that the conclusions reached in this study are applicable to the major agricultural areas of the state.

Irrigation is often expensive in Michigan, however more consideration of the economic aspects of irrigation system design and operation will reduce costs and result in greater acceptance of irrigation as a desirable production practice on a greater variety of crops. This in turn will result in a greater demand on existing water resources. The results of the evaluation of water development methods in this study should be useful in determining economical methods of extending surface and ground water supplies.

The results of this study indicate that development of ground water has a decided economic advantage over surface water in particular situations. This advantage, together with water right uncertainties associated with surface water supplies, makes the use of ground water particularly desirable for irrigation. This suggests that farmers should give more consideration to the use of ground water as a source of irrigation water supply. A complete ground water inventory of Michigan is an essential step for the development of this resource.

The wide variation in the design and operation of sprinkler systems found by this study implies that there was an educational need which was not being adequately met. This situation was also suggested during the interviews with the respondents. They asked questions regarding the hydraulics of sprinkler systems, soil-moisture-plant relationships, irrigation of certain crops during periods of high temperatures and humidity, and the advantages of using either well or surface water as a source of supply. Many of the answers can be found in research already completed while some may require new projects. The Cooperative Extension Service of Michigan State University occupies a position of high prestige and public confidence and is in an ideal position to supply this needed education.

During the period of this study the author noticed a reluctance by a number of persons to accept development of water resources as something desirable. It is this author's opinion that a flow resource, such as water should be intensely developed and used to enrich the state's economy.

This development can be for any single or combination of uses and it is recognized that the direction the development takes can result in conflict. Non-development by reason of "potential conflict" however is an economic loss to the state.

APPENDIX

TABLE a.--Characteristics of surface systems[a]

Acres Irri.	Investment: Sys-tem	Investment: Reser-voir	Reservoir Capac. in 10^5 Cu Ft	Pump Capac.: GPM	Pump Capac.: GPM/Ac	Dis. Water Pumped in Ft	Hours Oper. per Year	Cost per Acre-Inch: Fixed[b]	Cost per Acre-Inch: Oper-ating[c]	Cost per Acre-Inch: Total
10	$1104	$ . .	. .	256	26	700	32	$ 5.86	$3.20	$ 9.06
40	2772	. .	. .	330	8	500	100	3.67	2.06	5.73
30	2041	2200	3.4	550	18	640	200	2.01	1.18	3.19
23	2425	450	ditch	500	22	1000	40	5.32	2.34	7.66
10	2016	300	1.0	380	38	300	30	9.74	3.48	13.22
12	1614	315	0.7	352	39	1200	100	2.52	1.26	3.78
20	1670	150	0.08	300	15	1000	50	5.48	2.08	7.56
25	3355	5000	dike	800	32	1320	40	13.72	2.12	15.84
12	3825	750	1.7	400	33	2000	40	13.34	4.05	17.39
6	2290	650	lake	350	58	2000	30	12.42	4.28	16.70
50	1901	2340	4.2	500	10	1320	300	1.47	.97	2.44
33	5325	1000	2.9	850	26	2640	250	1.41	.93	2.34
20	5000	. .	. .	270	14	3000	500	1.62	2.31	3.93
7	2595	. .	. .	340	49	2640	175	1.91	1.81	3.72
35	1368	3000	6.8	450	13	300	125	4.18	1.22	5.40
80	2400	. .	. .	585	7	3000	80	2.27	1.79	4.06

[a]Data from farm survey, Berrien County, Michigan, 1960.

[b]Pump and mainline depreciated over 15 years, reservoir depreciated over 10 years. All interest calculated at .06 x ½ the investment.

[c]Labor, fuel, and equipment-repair. Equipment repair estimated at 0.03 x system investment.

TABLE b.--Characteristics of well systems[a]

Acres	Investment		Well Depth, Ft		Pump Capac.		Hrs. Oper.	Cost per Acre-Inch		
Irri.	Sys.	Well	Total	To Water	GPM	GPM/Ac	per Year	Fixed[a]	Oper.[b]	Total
43	$3400	$1672	100	18	360	8	150	$3.65	$2.15	$ 5.80
40	1900	800	58	18	300	7	250	1.42	1.22	2.64
25	2540	2860	210	?	375	15	154	3.33	1.84	5.17
30	1000	980	66	?	322	11	105	2.03	1.34	3.37
25	1950	2050	100	40	156	6	100	9.36	3.55	12.91
40	7681	3719	120	64	660	16	200	3.35	2.41	5.76
15	2800	1800	100	22	900	60	50	3.88	1.17	5.05
40	600	1855	33	11	181	4	600	.73	1.40	2.13
55	2100	1400	90	35	700	13	75	2.51	1.31	3.82
40	3000	1900	91	20	350	9	150	3.53	1.86	5.39
40	700	2110	65	7	280	7	150	2.19	1.88	4.07
38	700	1600	26	7	360	9	150	1.42	.97	2.39

[a]Data from farm survey, Berrien County, Michigan, 1960.

[b]Pump depreciated over 15 years. Well depreciated over 30 years. All interest calculated at .06 x ½ the investment.

[c]Labor, fuel, and pump-repair at 0.03 x pump investment.

TABLE c.--Data for water development System A

Distance Water Pumped Ft	Mainline Diameter Inches	Pumping Capacity GPM	Equip Invest-ment	Sump Invest-ment	Total Cost per Acre-Inch[a]
0	...	11.8	$1100	$320	$2.07
"	...	16.6	1500	"	2.42
"	...	33.2	2500	"	3.30
1000	4	11.8	1770	320	2.91
"	5	16.6	2410	"	3.39
"	6	33.2	3700	"	4.61
2000	4	11.8	2440	320	3.77
"	5	16.6	3320	"	4.39
"	6	33.2	4900	"	5.93
3000	5	11.8	3830	320	4.71
"	5	16.6	4230	"	5.33
"	8	33.2	9250	"	9.42
4000	5	11.8	4740	320	5.61
"	6	16.6	6300	"	6.92
"	8	33.2	11500	"	11.47

TABLE d.--Economical mainline selection for System A[a]

Total GPM	Pipe Dia. Inches	Head Loss per 100 Ft	Pipe Cost per Ft
283	4	5.3	$0.67
398	5	3.4	.91
797	6	5.2	1.20
...	8	...	2.25

[a]The economical pipe size was determined by computing the total cost of pumping per foot of pipe for the given quantities of water through various pipe sizes. A pumping period of 220 hours per year was assumed.

TABLE e.--Data for water development System B

Pump Setting Feet	Depth of Well Feet	Well Dia. Inches	Well Investment[a]	Pump Investment	Pump Capacity GPM/Acre	Total Cost per Acre-Inch
50	100	8	$2240	$2234	11.8	$3.91
"	"	10	2880	2303	16.6	4.25
"	"	12	3560	2882	33.2	5.05
50	200	8	3840	2234	11.8	4.61
"	"	10	4880	2303	16.6	5.13
"	"	12	5960	2882	33.2	6.11
50	300	8	5440	2234	11.8	5.32
"	"	10	6880	2303	16.6	6.01
"	"	12	8360	2882	33.2	7.17
100	100	8	2240	2690	11.8	4.55
"	"	10	2880	2970	16.6	5.08
"	"	12	3560	4050	33.2	6.33
100	200	8	3840	2690	11.8	5.26
"	"	10	4880	2970	16.6	5.97
"	"	12	5960	4050	33.2	7.38
100	300	8	5440	2690	11.8	5.97
"	"	10	6880	2970	16.6	6.85
"	"	12	8360	4050	33.2	8.44
150	200	8	3840	3440	11.8	6.17
"	"	10	4880	4214	16.6	7.31
"	"	12	5960	5457	33.2	8.88
150	300	8	5440	3440	11.8	6.88
"	"	10	6880	4214	16.6	8.19
"	"	12	8360	5457	33.2	9.93

[a]Well costs were calculated at $2.00 per foot per inch of the well diameter with 20 feet of screen allowed each well at the following costs: 8" at $32.00 per foot, 10" at $44.00 per foot, and 12" at $58.00 per foot.

TABLE f.--Data for water development System C

Distance Water Pumped Ft	Irri. Pump Capac. GPM/Ac	Cost of Small Pump[a]	Cost of Main-line	Cost Hold-ing Pond[b]	Cost per Acre-Inch Source to Pond[c]	Pond to Field[d]	Total
1000	11.8	$120	$ 530	$1000	$1.56	$1.78	$3.34
"	16.6	"	"	"	"	2.13	3.69
"	33.2	"	"	"	"	3.01	4.57
2000	11.8	150	1060	1000	2.09	1.78	3.87
"	16.6	"	"	"	"	2.13	4.22
"	33.2	"	"	"	"	3.01	5.10
3000	11.8	175	1590	1000	2.62	1.78	4.40
"	16.6	"	"	"	"	2.13	4.75
"	33.2	"	"	"	"	3.01	5.63
4000	11.8	200	2120	1000	3.14	1.78	4.92
"	16.6	"	"	"	"	2.13	5.27
"	33.2	"	"	"	"	3.01	6.15

[a]Electric horizontal centrifugal 70 gallons per minute unit.

[b]The holding pond was square and had a capacity of 48 acre-inches. Estimated cost does not include sealing.

[c]Electricity was estimated to cost 0.0125 per horsepower hour. It was expected that the unit could be hooked to an existing farm service and would operate at the low rate in the domestic schedule. If a separate meter were required, the rate would be approximately doubled.

[d]These are the same costs calculated for System A with the field located adjacent to the water source.

TABLE g.--Data for water development System D

Well Depth Ft	Well Investment[a]	Pump Investment[b]	Pump Set. Ft	Irr. Pump Capacity GPM/Acre	Cost per Acre-Inch: Source To Pond[c]	Pond to Field[d]	Total
50	$ 780	$ 730	25	11.8	$2.04	$1.78	$3.82
"	"	"	"	16.6	"	2.13	4.17
"	"	"	"	33.2	"	3.01	5.05
100	1180	730	25	11.8	2.22	1.78	4.00
"	"	"	"	16.6	"	2.13	4.35
"	"	"	"	33.2	"	3.01	5.23
100	1180	1320	75	11.8	2.82	1.78	4.60
"	"	"	"	16.6	"	2.13	4.95
"	"	"	"	33.2	"	3.01	5.83
150	1580	730	25	11.8	2.40	1.78	4.18
"	"	"	"	16.6	"	2.13	4.53
"	"	"	"	33.2	"	3.01	5.41
150	1580	1320	75	11.8	3.00	1.78	4.78
"	"	"	"	16.6	"	2.13	5.13
"	"	"	"	33.2	"	3.01	6.01
150	1580	1670	125	11.8	3.47	1.78	5.25
"	"	"	"	16.6	"	2.13	5.60
"	"	"	"	33.2	"	3.01	6.48

[a]A 4-inch diameter well with 20 feet of screen. The well cost was estimated at $8.00 per foot and the screen; $19.00 per foot.

[b]A 70 gallons per minute deep well turbine operating at 3500 rpm and driven with an electric motor.

[c]Electricity was estimated to cost 0.0125 per horsepower hour. It was expected that the unit could be hooked to an existing farm service and would operate at the low rate in the domestic schedule. If a separate meter were required, the rate would be approximately double.

[d]These are the same costs calculated for System A with the field located adjacent to the water source.

TABLE h.--Data for water development System E

Dis. Well To Field Ft	Investment in Mainline[a]	Investment in Holding Pond	Cost per Acre-Inch			
			Main-line & Res.	Well Rent[b]	Irrigation Pump[c]	Total
1000	$ 530	$1000	$1.37	$2.44	$1.78	$5.59
"	"	"	"	"	2.13	5.94
"	"	"	"	"	3.01	6.82
2000	1060	1000	1.83	2.44	1.78	6.05
"	"	"	"	"	2.13	6.40
"	"	"	"	"	3.01	7.28
3000	1590	1000	2.30	2.44	1.78	6.52
"	"	"	"	"	2.13	6.87
"	"	"	"	"	3.01	7.75
4000	2120	1000	2.76	2.44	1.78	6.98
"	"	"	"	"	2.13	7.33
"	"	"	"	"	3.01	8.21

[a]All 3-inch diameter.

[b]Basis for this charge is discussed on pages 36 and 37.

[c]These are the same costs calculated for System A with the field located adjacent to the water source.

TABLE i.--Operation of 70 gallons per minute pump and 4 acre-foot holding-pond to provide adequate water for three $1\frac{1}{2}$-inch irrigations in 3 weeks to 24 acres

Water Quantity in Acre-Inches per Acre	Description
2.0	in storage
+ 1.1	pumped into pond 1st week
- 1.5	removed 1st week
1.6	available at start of 2nd week
+ 1.1	pumped into pond 2nd week
- 1.5	removed 2nd week
1.2	available at start of 3rd week
+ 1.1	pumped into pond 3rd week
- 1.5	removed 3rd week
.8	available at start of 4th week

INTERVIEW DATA SHEET
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Item and Description	Price
Pump Make_______ gpm____ Head____ Turb.___ Cen.___	______
Motor H.P._____ Elec.___ Gas.___ Diesel___ Trac.___	______
Mainline, Dia._____ Total Feet_____	______
_____ _____	______

Source of Water

Well____ Dia.____ Depth____ Ft., Screen Length_____ ______

Pumping Level____ Ft. W.T. Lvl.____

Reservoir____ Dimensions______ x ______ x ______ ______

Stream____ Distance from field irrigated______ Ft.

Labor

Maintenance of pumping plant__________ man hours/yr.

Putting up and taking down mainline__________ man hours/yr.

Installing pump in stream__________ man hours/yr.

Other Information

Sprinkler spacing_____ x _____. Nozz. Dia._____ x _____ No._____

Acres Irrigated____. No. of Irrigations in 1959_____ 1960 _____

Fuel Consumption_____ Gal/hr. Hours of Operation 1959_______

Fuel Cost_________

Coupler Brand____________________

From whom purchased____________________

Satisfied_______ yes,_______ no

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